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SPECIFICATION

1. Title of the Invention: METHOD FOR MANUFACTURING NON-DIRECTIONAL MAGNETIC STEEL SHEET EXCELLENT IN MAGNETIC PROPERTIES

2. Claims

(1) A method for manufacturing a non-directional magnetic steel sheet excellent in magnetic properties, comprising the steps of:

subjecting a magnetic steel slab comprising (in weight %):

C: up to 0.02%,

Si: under 1.8%,

Mn: up to 2.0%,

P: up to 0.15%,

S: up to 0.02%, and

the balance iron and incidental impurities to a hot finish rolling at a temperature in α region from start to end, keeping a temperature within a range from the finish rolling end temperature to above 750°C for 7 seconds, then cooling the steel sheet by pouring water, coiling the same at a temperature under 680°C, and subsequently, cold-rolling and annealing the same.

(2) A method for manufacturing a non-directional magnetic steel sheet excellent in magnetic properties, comprising the steps of:

subjecting a magnetic steel slab comprising (in weight %):

C: up to 0.02%,

Si: under 1.8%,

Mn: up to 2.0%,

P: up to 0.15%,

S: up to 0.02%,

further containing one or more of:

Cu: from 0.01 to 1.0%,

Sn: from 0.02 to 0.20%,

Sb: from 0.010 to 0.30%, and

B: from 0.0003 to 0.0050%, and

the balance iron and incidental impurities to a hot finish rolling at a temperature in α region from start to end, keeping a temperature within a range from the finish rolling

end temperature to above 750°C for 7 seconds, then cooling the steel sheet by pouring water, coiling the same at a temperature under 680°C, and subsequently, cold-rolling and annealing the same.

(3) A method for manufacturing a non-directional magnetic steel sheet excellent in magnetic properties, comprising the steps of:

subjecting a magnetic steel slab comprising (in weight %):

C: up to 0.02%,

Si: under 1.8%,

Mn: up to 2.0%,

P: up to 0.15%,

S: up to 0.02%, and

the balance iron and incidental impurities to a hot finish rolling at a temperature in α region from start to end, keeping a temperature within a range from the finish rolling end temperature to above 750°C for 7 seconds, then cooling the steel sheet by pouring water, coiling the same at a temperature under 680°C, and subsequently, cold-rolling and annealing the same, and skin-pass-rolling the same.

(4) A method for manufacturing a non-directional magnetic steel sheet excellent in magnetic properties, comprising the steps of:

subjecting a magnetic steel slab comprising (in

weight %):

C: up to 0.02%,

Si: under 1.8%,

Mn: up to 2.0%,

P: up to 0.15%,

S: up to 0.02%,

further containing one or more of:

Cu: from 0.01 to 1.0%,

Sn: from 0.02 to 0.20%,

Sb: from 0.010 to 0.30%, and

B: from 0.0003 to 0.0050%, and

the balance iron and incidental impurities to a hot finish rolling at a temperature in α region from start to end, keeping a temperature within a range from the finish rolling end temperature to above 750°C for 7 seconds, then cooling the steel sheet by pouring water, coiling the same at a temperature under 680°C, and subsequently, cold-rolling and annealing the same, and skin-pass-rolling the same.

3. Detailed Description of the Invention

(Technical Field of the Invention)

The present invention relates to a manufacturing method of a non-directional magnetic steel sheet excellent both in core loss and magnetic flux density.

(Description of the Related Art)

A non-directional magnetic steel sheet is used as a

core material for a general-purpose motor of large-sized or middle-sized rotating machine, an automotive motor, a home electrical appliance motor, or a transformer. For this purpose, steel sheets are classified into, for example, S9 to S50 grades depending upon the magnetic level, and are used for each of various applications in response to the purpose of application of the desired electric appliance product.

In view of the recent tendency toward energy saving, improvement of properties of electric appliances, and downsizing of equipment, there is an increasing demand for improved magnetic properties of core materials used in these electric appliances. Particularly, it is important to further improve magnetic properties of medium- to low-grade non-directional magnetic steel sheets, for example, of S30 or lower used in general-purpose motors, automotive motors and home electrical appliances motors.

Power loss occurring in an electric appliance mainly comprises core loss and depends upon the core loss of non-directional magnetic steel sheet serving as a material. Core loss may be reduced by increasing the Si content, but this leads to an increase in cost and further to a decrease in magnetic flux density. Since a decrease in magnetic flux density would require a large exciting current. The resulting increase in power loss leads to a serious problem

in general-purpose motors frequently activated and deactivated.

Under these circumstances, it is necessary to achieve a non-directional magnetic steel sheet low in core loss and high in magnetic flux density.

Regarding manufacture of a non-directional magnetic steel sheet, proposal is made to improve magnetic properties. For example, Japanese Examined Patent Publication No. 60-56403 discloses conducting a high-temperature short-period annealing at 800°C for two minutes or less after hot rolling to an extra-low carbon magnetic steel slab containing from 0.3 to 2.0% Si.

Other examples include a method of, in hot rolling of a magnetic steel, hot-rolling at a temperature lower than the central value between Ar_3 and Ar_1 transformation points and higher than 750°C, and coiling at a temperature higher than 680°C (Japanese Unexamined Patent Application Publication No. 56-38420); a method of hot rolling t two-phase regions γ and α below Ar_3 transformation point and above Ar_1 transformation point, and after slow cooling, coiling the sheet at 500-600°C (JP No. 56-38422); and a method of hot-rolling at 700-900°C by specifying Si and Al contents in γ-phase (JP No. 62-384016). These methods provide respective advantages.

(Problems to be Solved by the Invention)

Applying a hot-rolled sheet annealing has difficulty of

leading to a higher cost. The aforementioned hot rolling is applied in an attempt to increase the magnetic flux density through reduction of {111}, {211} plane components and to somewhat increase crystal grains having {110}, {100} plane components. This may however cause a difference in crystal texture in the thickness direction. The magnetic flux density cannot be considered to be sufficiently high.

It is an object of the present invention to provide a manufacturing method which permits obtaining a middle to low class non-directional magnetic sheet of S20 grade or lower, low in core loss and higher in magnetic flux density and stable. In addition, another object is to provide a manufacturing method of a non-directional magnetic steel sheet, which gives a high thickness accuracy, free from an edge drop, a satisfactory yield and a large reduction of cost.

(Means for Solving the Problems)

As a result of repeated experiments and considerations to achieve the aforementioned object, the present inventors obtained findings that, when hot-rolling an extra-low-carbon magnetic steel slab, control of temperature not only of the hot-rolling finishing temperature, but also control of temperature for all regions from start to end of finish rolling, retention of a high temperature during coiling after finish hot rolling, and the coiling conditions are

important.

The present invention was developed on the basis of these new findings, and provides a manufacturing method of a non-directional magnetic steel sheet excellent in magnetic properties, comprising the steps of:

subjecting a magnetic steel slab comprising (in weight %):

C: up to 0.02%,

Si: under 1.8%,

Mn: up to 2.0%,

P: up to 0.15%,

S: up to 0.02%,

further containing one or more of:

Cu: from 0.01 to 1.0%,

Sn: from 0.02 to 0.20%,

Sb: from 0.010 to 0.30%, and

B: from 0.0003 to 0.0050%, and

the balance iron and incidental impurities to a hot finish rolling at a temperature in α region from start to end, keeping a temperature within a range from the finish rolling end temperature to above 750°C for 7 seconds, then cooling the steel sheet by pouring water, coiling the same at a temperature under 680°C, and subsequently, cold-rolling, annealing or skin-pass-rolling the same.

The present invention will now be described in detail.

First, the chemical composition of the steel used in the present invention will be described.

C is a component which deteriorates magnetic properties. A high C content causes an increase in core loss and causes magnetic aging. The C content should therefore be up to 0.02%.

Si is contained so as to reduce core loss through increase in specific resistance. An increase in the Si content causes a decrease in magnetic flux density and leads to a higher cost. The Si content should be lower than 1.8%. I is not necessary to specify a lower limit, but it should preferably be 0.05%.

Mn has an effect of hard cracking during hot rolling, and has an additional effect of reducing core loss while avoiding deterioration of the magnetic flux density. A high Mn content leads to a high-cost operation. The Mn content should therefore be up to 2.0%.

P brings about advantages of improving steel sheet hardness and improving punchability. A high P content results in core loss and deterioration of magnetic flux density. The P content should therefore be up to 0.15%.

S generates non-metal inclusions, impairs crystal growth, and is detrimental for core loss. The S content should therefore be up to 0.02%.

The steel should preferably contain additionally, as

required, one or more of 0.01-1.0% Cu, 0.02-0.20% Sn, 0.010 to 0.30% Sb, and 0.0003-0.0050% B.

Cu, Sn, Sb and B has the effect of exerting an influence on the texture and improving the magnetic flux density. In order to make valid this effect, the Cu content should be higher than 0.010%, the Sn content should be higher than 0.02, the Sb content should be higher than 0.010%, and the B content should be higher than 0.0003%. An excessively high content of any of these elements causes on the other hand, deterioration of core loss. The upper limit is therefore 1.0% for Cu, 0.20% for Sn, 0.30% for Sb, and 0.0050% for B.

A magnetic steel slab containing the aforementioned steel components and the balance iron and incidental impurities is manufactured by a known process such as such as continuous casting.

The magnetic steel slab is heated and hot-rolled. The hot rolling process is an important factor in the present invention: hot finish rolling is accomplished from start to completion, not in the γ region or in the dual phase region of α and γ, but in α phase. This will be considered with reference to the experimental data.

The magnetic steel slabs having the steel chemical composition shown in Table 1 were used as samples. Hot rolling was carried out at a starting temperature and an end

temperature, with high temperature retention from end of rolling to coiling, and a coiling temperature under conditions shown in Table 2. Then, after descaling, the thickness was converted from 2.5 mm to 0.50 mm through hot rolling. Annealing was applied under conditions including 800°C x 10 seconds. The core loss W15/50 and the magnetic flux density B_{50} were measured. The result is shown together in Table 2.

The Ar_3 transformation point and the Ar_1 transformation point of the samples were separately measured. The result is also shown in Table 2.

TABLE 1

SAMPLE SYMBOL	STEEL CHEMICAL COMPOSITION (%)						
	C	Si	Mn	P	S	Al	N
1	0.0053	0.20	0.21	0.036	0.0082	Tr	0.0028
2	0.0133	0.70	0.71	0.036	0.0082	Tr	0.0018

TABLE 2

SAMPLE SYMBOL	HOT ROLLING CONDITIONS				MAGNETIC PROPERTIES		TRANSFORMATION POINT		WIDDTH-DIRECTION THICKNESS DEVIATION (μm)
	START TEMPERATURE (°C)	END TEMPERATURE(°C)	HIGH TEMPERATURE RETENTION (°C x SEC)	COILING TEMPERATURE (°C)	W50/50 (W/Kg)	B50 (tesla)	Ar_3	Ar_1	
1A	841	788	OVER 755 x 6	640	6.46	1.78	990	845	1
1B	958	901	OVER 760 x 1	745	6.93	1.73	890	845	5
1C	890	845	OVER 750 x 2	678	6.66	1.76	890	845	5
2A	855	803	OVER 750 x 7	658	6.12	1.74	925	860	2
2B	984	927	OVER 750 x 1	751	6.51	1.71	925	860	6
2C	928	880	OVER 760 x 2	688	6.37	1.72	925	860	4

As is clear from this experimental result, samples for which all operations from start to end of hot rolling were

accomplished in the α-phase region, with a high temperature retention after hot rolling, and the water-jet-cooled and coiled at a low temperature (1A and 2A) were more excellent both in core loss $W_{15/50}$ and magnetic flux density B_{50} as compared with the samples hot-rolled in the γ-phase and in the dual phase of γ and α (1B, 2B, 1C and 2C). The samples show no thickness deviation in the width direction, and are more excellent in thickness accuracy. The thickness deviation was measured on product sheet.

For the hot rolling, therefore, both the rolling start temperature and the end temperature must be under the Ar_1 transformation point. After the completion of hot rolling, the temperature is retained at a high level between the rolling end temperature an above 750°C within seven seconds for increasing the magnetic flux density, reducing the core loss, achieving a uniform crystal texture of the hot-rolled sheet, and simultaneously, raising the thickness accuracy. The period should preferably be over 2 seconds to 7 seconds. If this high temperature retention condition is not satisfied, desired advantages are unavailable. Subsequently, the sheet is cooled by water jet and coiled at a temperature lower than 680°C. Dispersion of magnetic properties is prevented by keeping a coiling temperature under 680°C.

After hot rolling, the rolled sheet is descaled, cold-rolled, and annealed. When a semi-process non-directional

magnetic steel sheet is desired, a skin-pass rolling is applied. Skin-pass rolling should preferably be applied with a draft of 2 to 10%. In the present invention, application of skin pass and stress relief annealing brings about remarkable improvement of magnetic properties.

(Embodiment)

An embodiment of the present invention will now be described.

Embodiment

Magnetic steel slabs having steel chemical compositions as shown in Table 3 were used as samples. Hot rolling was carried out under the conditions shown in Table 4. The high temperature retention was performed during the period from end of rolling to the start of water-jet cooling. Thereafter, the hot-rolled sheet was cold rolled to reduce thickness from 2.5 to 0.50 mm, and annealing was conducted at 800°C x 10 seconds. A skin-pass rolling at 9% was applied to some samples, and a stress relief annealing was performed under conditions including 750°C x 120 minutes.

After the aforementioned annealing and after the stress relief annealing, the core loss $W_{15/50}$, and the magnetic flux density B_{50} were measured. The result is shown together in Table 4. The thickness in the sheet width direction was measured after annealing. Deviation of thickness is also shown in the table.

TABLE 3

SAMPLE SYMBOL	STEEL CHEMICAL COMPOSITION (%)										
	C	Si	Mn	P	S	Al	N	Cu	Sn	Sb	B
3	0.0036	0.11	0.13	0.07	0.0038	Tr	0.0016				
4	0.0042	0.34	0.22	0.07	0.0040	Tr	0.0013				
5	0.0040	0.50	0.50	0.05	0.0013	0.37	0.0018	0.20	0.09		
6	0.0033	0.87	0.25	0.06	0.0068	Tr	0.0022			0.22	
7	0.0032	0.52	1.05	0.05	0.0022	0.20	0.0024				0.0025
8	0.0036	0.11	0.13	0.07	0.0038	Tr	0.0016				
9	0.0042	0.34	0.22	0.07	0.0040	Tr	0.0013				
10	0.0032	0.52	1.05	0.05	0.0022	0.20	0.0024				

NOTE: 7 AND 10 SHOW SKIN-PASS VALUES

3-7 REPRESENT VALUES OBTAINED IN THE PRESENT INVENTION, AND 8-10 COVER COMPARATIVE EXAMPLES.

TABLE 4

SAMPLE SYMBOL	HOT ROLLING CONDITIONS				MAGNETIC PROPERTIES		TRANSFORMATION POINT		WIDDTH-DIRECTION THICKNESS DEVIATION (μm)
	START TEMPERATURE (°C)	END TEMPERATURE (°C)	HIGH TEMPERATURE RETENTION (°C × SEC)	COILING TEMPERATURE (°C)	W15/50 (W/kg)	B50 (testa)	Ar_3	Ar_1	
3	830	761	OVER 750 X 6	635	7.80	1.77	890	840	2
4	838	780	OVER 760 X 6	642	7.00	1.76	900	850	1
5	850	801	OVER 765 X 5	665	6.60	1.78	920	860	3
6	858	802	OVER 755 X 6	670	6.50	1.76	940	870	2
7	800	770	OVER 750 X 4	620	3.90	1.73	860	800	1
8	1010	910	OVER 750 X 2	750	8.10	1.74	890	840	5
9	1015	912	OVER 750 X 1	755	7.20	1.74	900	850	6
10	980	870	OVER 750 X 1	700	4.40	1.71	860	800	6

(Advantages)

As is evident from this embodiment, according to the present invention, a non-directional magnetic steel sheet having a high magnetic flux density, a low core loss, and a very slight thickness deviation in the width direction are available.

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